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STUDY OF THE VARIATIONS OF THE MACROSCOPIC ELECTRIC PARAMETERS OF A SOLAR CELL ACCORDING TO THE USE TEMPERATURE

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ABSTRACT
The Research has for objective to increase the performances of the thin film solar cells. Many scientific publications were interested by the development of the thin films which make the cell. Others based their research on the technology of the cell and the experimental elaboration conditions.
In this paper we are interested by the performances of the cell during its utilization period. We study the influence of the use temperature on the macroscopic electric parameters of the solar cell. The range of use temperatures varies from 270K to 320K with a step of 10K. The type of cell studied is a $Cu(In, Ga)Se_2$ thin film solar cell. The elucidated physical parameters are the characteristic density of current-voltage J-V, the open circuit voltage Voc, the short circuit current density Jsc, the form factor FF and the cell efficiency η.
We find at the end of this investigation that the temperature of 270K gives the best electric parameters with a cell efficiency equal to 20,65%. These parameters decrease with the increase in the use temperature but remain significant.

KEYWORDS: AMPS, use temperature, electric parameters, $Cu(In,Ga)Se_2$ thin film, solar cell.

INTRODUCTION
The use of the thin films begins with a study from their elaboration techniques. [1] This research was then directed towards the improvement of the performances of the cell by taking to account the physical properties of the layers which make the cell, the thickness of the layers, the technology of the cell, etc… [2]-[3]. The use of the thin films in the technology of the solar cells is a well maitrized technique which does not stop improving in the course of time.[4]-[5]. The development of the use of $CuInSe_2$ thin film solar cell and its derivatives should not be limited to the improvement of the experimental conditions such as the deposit voltage, the deposit temperature, the time of annealing and the thin layers thickness. These already elucidated parameters made it possible to increase the performances of the solar cells.[6]-[8]

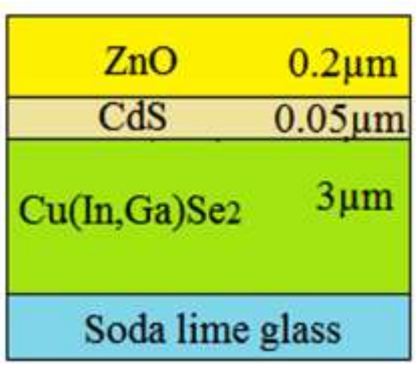

Figure 1: Representative diagram of the type of cell studied.

However we are interested by the extra experimental parameters. We study the effect of the use temperature of the cell on the macroscopic electric parameters. These parameters are the density of current-voltage characteristic, the open circuit voltage Voc, the short circuit current density Jsc, the form factor FF and the cell efficiency η. The use temperatures considered are 270K, 280K, 290K, 300K, 310K and 320K. Indeed we take to account the temperatures from 0°C to 50°C, the cells being exposed to the sun. We neglect the conditions of encapsulation of the cells, the optical transmission of glass, the slope of the cells and the shade phenomena. All the properties of the cells are taken into account. The solar cells which are the subject of our study are indicated by the Figure 1. The study of the macroscopic electric parameters passes by a perfect control of the equations which govern the physical phenomena which occur in the cell. These equations allow us to deeply understand the physical phenomena which occur in the cell going from the absorption of the incidental solar photons to the creation of the D.C. current.

MATERIALS AND METHODS

To undertake our study, catches were not carried out in a photovoltaic field but we base our study on three sections. The first shutter consists in carrying out a simulation using the Analysis of Microphotoelectonics Structures AMPS. This last is a software developed by Fonash et al..It is conceived for the simulation of the thin film solar cells. The layers of these structures can be single-crystal, polycrystalline, amorphous or even of the combinations.[9]-[10]
To carry out this simulation we use proven parameters of which certain are indicated by table 1.

Table 1: Some physical parameters of the layers which constitute the studied cells

Physical parameters	Window layer ZnO	Tampon layer CdS	Absorber layer $Cu(In, Ga)Se_2$
Thickness (µm)	0.2	0.05	3
Gap (eV)	3.3	2.4	1.15
Permittivity	9	10	13.6
Density of donors Nd (cm^{-3})	1×10^{18}	1×10^{18}	---
Density of acceptors Na (cm^{-3})	---	---	2×10^{16}

Each layer which constitutes the cell was studied in our preceding work already published.
The second shutter of our work concerns the handling of the equations which govern the physical parameters which intervene in the heart of the solar cell. These equations are the Poisson's equation, the equations of continuity and the transport equations. We had to develop these equations before.[11]
This shutter enables us to see the convergence of the results obtained with simulation.
The third shutter of our work concerns the tracing of the characteristics studied with Matlab. It is mathematical software which enables us to obtain the curves of variations of the characteristics studied according to the ambient temperature.
The study is carried out under AM1.5 spectrum with an incidental power of sunning $1000W.m^{-2}$. One takes into account the totality of radiation wavelengths which reach the window layer. We start by studying the variation of the current density according to the voltage for use temperatures from 270K to 320K. This variation enables us to approach the study of the other macroscopic electric parameters like the open circuit voltage Voc, the short circuit current Jsc, the form factor FF and the efficiency η.
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RESULTS AND DISCUSSION

- **Effect of the use temperature on the current density-voltage characteristic.**

The Figure 2 gives us the variation of the density of current-voltage characteristic according to the temperature. Indeed under illumination, the D.C. current delivered by the cell is related to the voltage by the relation:

$$I = I_{ph} - I_S\left[\exp\left(\frac{qU}{k_B T}\right) - 1\right] \qquad (1)$$

The current density is this D.C. current brought back to the unit of area of the cell. It is related to the potential of the cell U and the temperature T which are in the exponential term.

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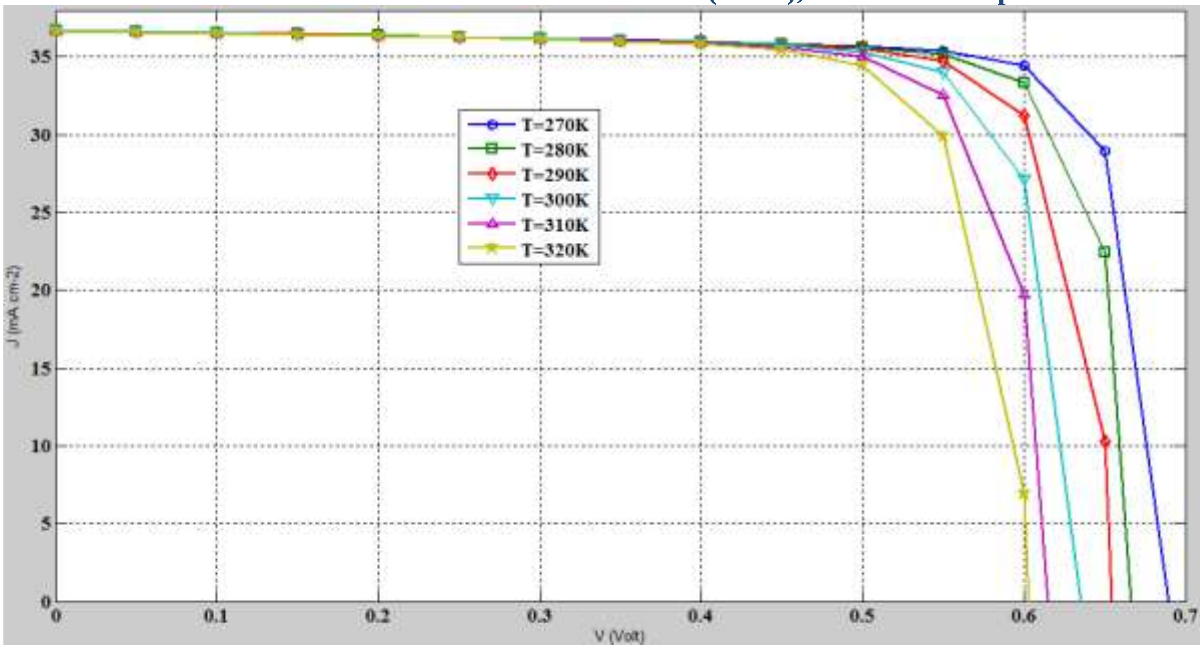

Figure 2: The density of current-voltage characteristics according to the use temperatures of the Cu(In, Ga)Se_2 thin film solar cell.

The Figure 2 shows us conventional characteristics. We notice that the temperature affects more the open circuit voltage Voc than the short circuit current density. The open circuit voltage decreases with the increase in the temperature while the short circuit current density almost does not vary if we stick to figure 2. We also notice that the Maximum Power Point MPP is higher for the cell used at the temperature of 270K which is the lowest temperature. Then this MPP decreases with the increase in the temperature.

For better determining the influence of the temperature we will study the behavior of the other electric parameters deduced from the current density-voltage characteristics.

- **Effect of the use temperature on open circuit voltage Voc**

The Figure 3 shows the characteristics of the variation of the open circuit voltage according to the use temperature. Indeed the open circuit voltage Voc is evaluated while applying:

$$V_{oc} = R_{sh}\left\{J_{ph} - J_s\left[e^{\frac{qV_{co}}{nk_BT}} - 1\right]\right\} \qquad (2)$$

As envisaged on the one hand by the figure 2, which gives the current density-voltage characteristics and on the other hand by the relation (2), we note a fall of the open circuit voltage with the increase of the temperature. Its decrease is quasi closely connected and it passes from 0.690V for T=270K to 0.603V for T=320K. We then note a difference in voltage of 87mV for a difference in temperature of 50C.

Physically the increase in the temperature increases the number of minority carriers stored at the junction and the cell has the capacity to behave like a voltage generator in the absence of current.

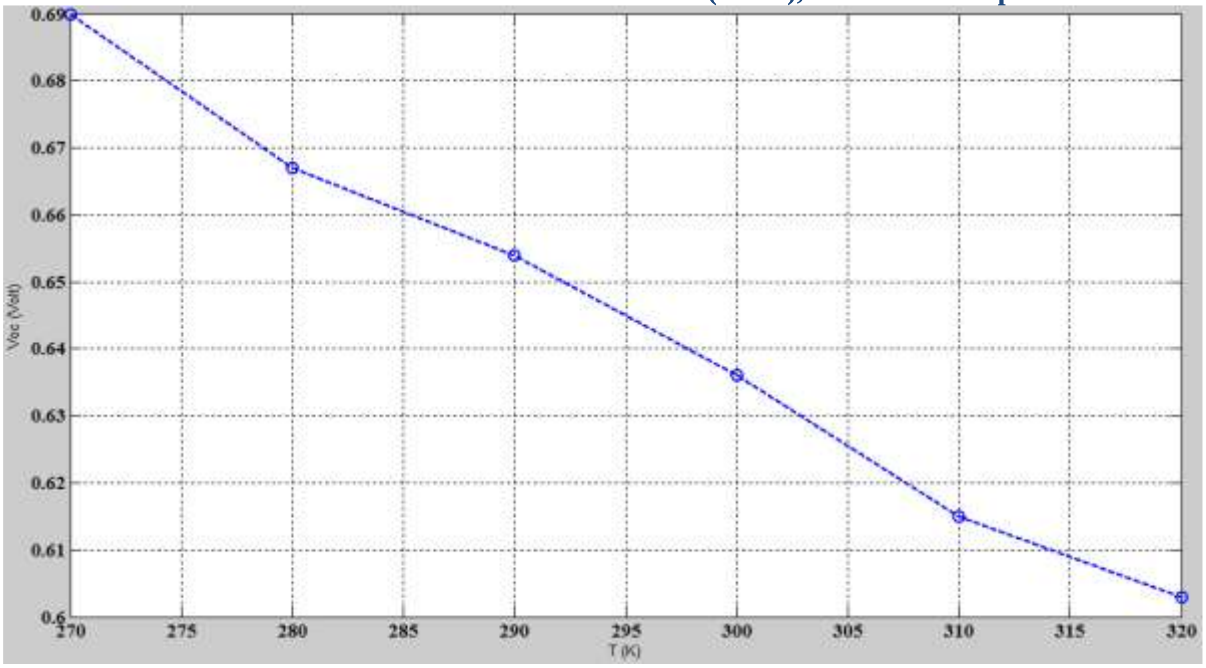

Figure 3: The variation of the open circuit voltage according to the use temperature of the Cu(In, Ga)Se$_2$ thin film solar cell.

- **Effect of the temperature of use on the density of current of short Jsc circuit**

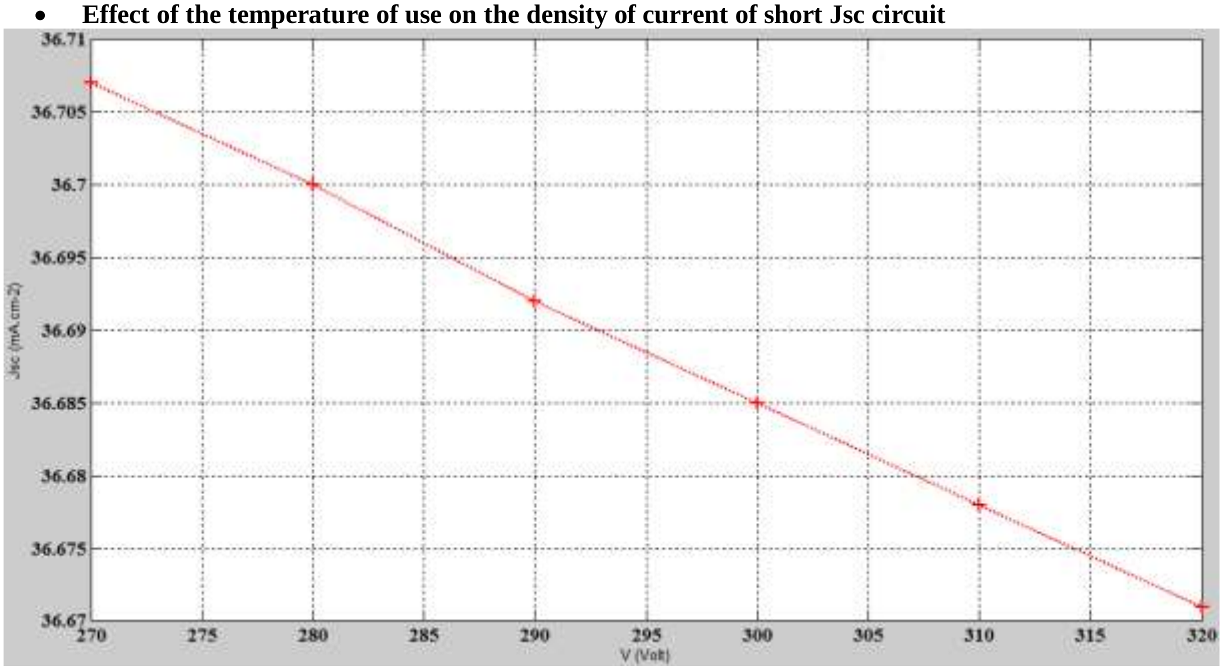

Figure 4: The variation of the short circuit current density Jsc according to the use temperature of the Cu(In, Ga)Se$_2$ thin film solar cell.

The Figure 4 presents to us the variation of the short circuit current density Jsc according to the use temperature of the cell. The Jsc can indeed be given starting from the relation that binds it to the temperature:

$$J_{sc} = \left[J_{ph} - J_s \left(e^{\frac{qJ_{cc}R_s}{nk_BT}} - 1 \right) \right] \left(1 - \frac{R_s}{R_{sh}} \right) \qquad (2)$$

This relation shows us that we should expect a decrease of the short-circuit current density according to the use temperature. This is confirmed by the figure 4 which indicates this decrease. The Jsc passes indeed from 36.707mA.cm^{-2} to 36.671mA.cm^{-2} when we passe from 270K to 320K. It's a reduction of 0.036mA.cm $^{-2}$ for a variation in temperature of 50°C.

The increase in the temperature increases at the front of the cell the number of carriers which can be collected. The cell has the capacity to behave as a generator of current when no voltage is delivered.

If we take into account together the fall in the open circuit voltage and the fall in the short circuit current density, we can consider easily that the generation of the carriers is supported by the increase in the temperature. This phenomenon passes by thermal agitation and other parameters related to the generation rate of the carriers. This explains the fact that the number of carriers stored at the junction and the number of carriers at the front of the cell increase.

- **Effect of the use temperature on the form factor FF**

The form factor of a cell is an electric parameter which makes it possible to attest the quality of the cell. Indeed by analogy it corresponds to the surface of the largest rectangle we can register under the density of current-voltage characteristic.The form factor can be evaluated while applying:

$$FF = \frac{V_m I_m}{V_{co} I_{cc}} \qquad (7)$$

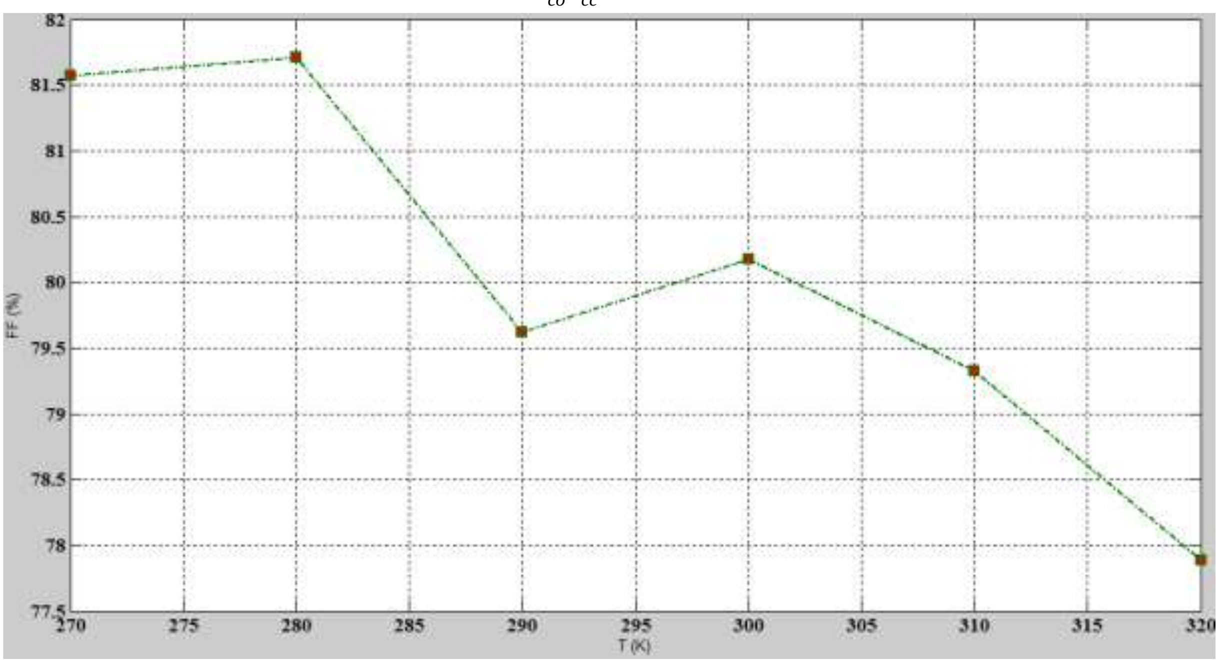

Figure 5: The variation of the form factor FF according to the use temperature of the Cu(In, Ga)Se$_2$ thin film solar cell.

The Figure 5 shows a decrease of the form factor according to the temperature. This decrease is disturbed at a use temperature of 290K because it drops up to 79.62% then it goes up to 80.17% for the temperature of 300K. This fall of the form factor is due to the importance of the product of the open circuit voltage and the short circuit density of current for a use under a temperature of 290K. This product of Voc and Jsc evolving more quickly than the product of maximum voltage V_m and the maximum current density J_m, we notice a fall of the form factor with the increase in the temperature.

- **Effect of the use temperature on the solar cell efficiency η**

The cell efficiency is the principal characteristic which makes it possible to judge the quality of the cell. It is expressed in % and can be given while applying:

$$\eta = \frac{FF \times V_{oc} \times I_{sc}}{P_{in}} \quad (4)$$

It is a physical parameter which takes into account the other preceding macroscopic electric parameters and the power of the incidental light. The Figure 6 shows us the variation of the cell efficiency according to the use temperature of the cell.

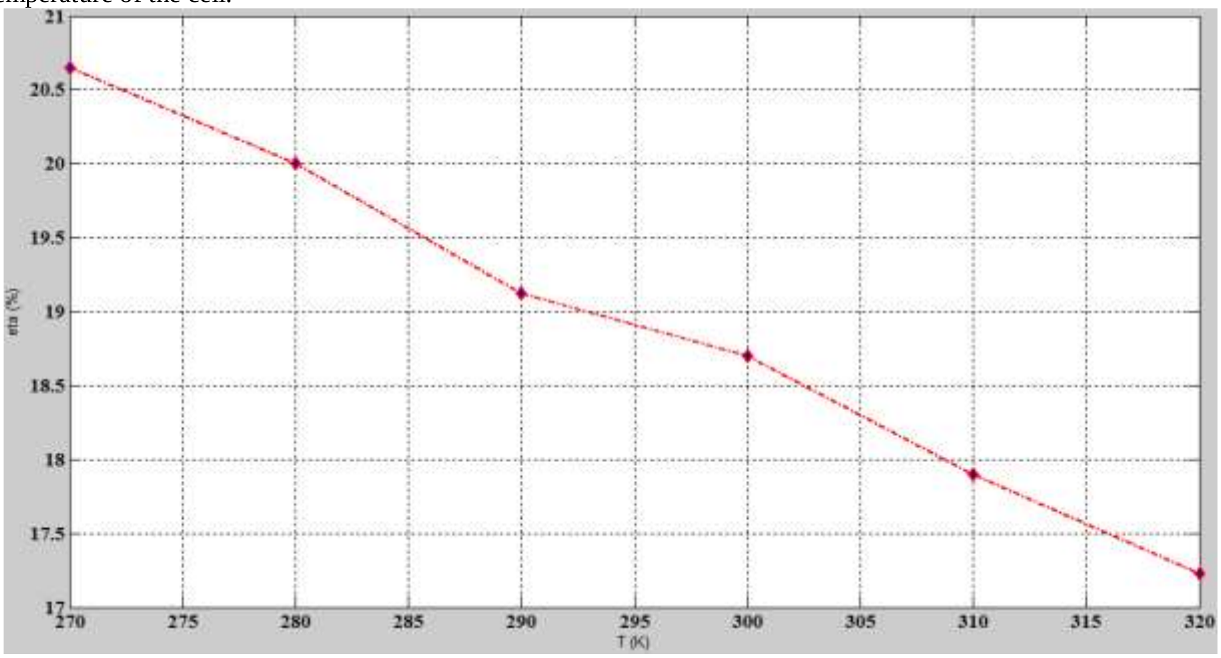

Figure 6: The variation of the efficiency according to the use temperature of the Cu(In, Ga)Se$_2$ thin film solar cell.

The solar cell efficiency decreases with the increase in the temperature. This efficiency passes from 20.65% for T=270K to 17.23% for T=320K. This corresponds to a reduction of 3.42% for a variation in temperature of 50K.
The beams of incidental solar rays should increase the photogeneration. But this solar illumination is accompanied by the rise of the use temperature which slows down the photogeneration. The number of charge carriers decreasing with the increase of the use temperature we note a fall of the cell efficiency.

CONCLUSION

The use temperature of the solar device is a physical parameter which has a direct influence on the macroscopic parameters of the cell. The study of this influence on the density of current-voltage characteristic, the open circuit voltage Voc, the short circuit current density FF, the form factor FF and the cell efficiency enables us to conclude that the optimal parameters were obtained with a use temperature of 270K. The density of current-voltage characteristics show that the open circuit voltage Voc is more affected than the short circuit current density Jsc. Concerning the form factor FF it remains significant on all the range of the use temperature. In spite of its reduction with the temperature, it remains higher than 79%. As regards the efficiency we also note that there remains significant and higher than 17%. However the increase of the use temperature causes a fall of the efficiency equal to 3.42%.

REFERENCES

[1] T. Negami, T. Satoh, Y. Hashimoto, S. Nishiwaki, S. –I. Shimakawa, S. Hayaski, "Large area CIGS absorbers prepared by physical vapor deposition", Sol. Energy Mater. Sol. Cells 67 (2001) 1.
[2] W. E. Devaney, W. S. Chen, J. M. Stewart, R. A. Mickelsen, "Structure and properties of high efficiency ZnO/CdZnS/CuInGaSe$_2$ solar cells", IEEE Trans. Electron Devices 37 (1990) 428.
[3] J. B. Pang, Y. A. Lai, Q. He, H. Wang, W. L. Jiang and al., "Preparation and characteristics of MoSe2 interlayer bifacial Cu(In,Ga)Se2 solar cells", Physics Procedia 2012, Vol. 32, pp 372-378.

[4] D. Lincot, J. F. Guillemoles, S. Taunier, D. Guinard, J. Sicx-Kurdi and al., "Chalcopyrite thin film solar cells by electrodeposition", Solar Energy 77 (2004) 725-737.

[5] Amit Soni, Alpa Dashora, Vikas Gupta, C. M. Arora and B. L. Ahuja, "Use of chalcopyrite semiconductors $CuXSe_2$ (X=Al, Ga and In) in solar cells: a theoretical study", International Journal of Sustainable Energy Vol 32, Issue 1, pp 18-26, (2013).

[6] C. J. Huang, T. H. Meen, M. Y. Lai, W. R. Chen, "Formation of $CuInSe_2$ thin films on flexible substrates by electrodeposition (ED) technique", Solar Energy Materials and Solar Cells 82 (2004) 553-565.

[7] Liu Fang-Yang, Liu Ying, Zhang-Zhi-An, Lai Yan-Qing, Lie Jie and Liu Ye-xiang, "Pulse-plating electrodeposition and annealing treatment of $CuInSe_2$ films", Trans. Nonferrous Met. Soc. China 18 (2008) 884-889.

[8] A. K. Ehemba, M. Dieng, D. Diallo, I. Wade, M. Socé, "The influence of the type and the thickness of the window layer on the electric parameters of the $Cu(In,Ga)Se_2$ thin film solar cell", The International Journal of Engineering and Science (IJES), Vol. 4, Issue 10, pp 81-86 (2015).

[9] Yimin Liu, Daniel Henzel and Angus Rockett, "a revised version of the AMPS simulation code", Scholarship of State University of Nankai, in Tanjin, China and Université of Illinois, Urbana, the United States Bourses d'Etat Université de Nankai, à Tanjin, Chine et Université de l'Illinois, Urbana, Etats-Unis.

[10] Nina E. Gorji, Uzo Reggiani and Leonardo Sandrolini, "A simple model of photocurrent density of a gradded band gap CIGS thin film solar cell", Solar Energy 86 (2012), pp 920-925.

[11] Alain Kassine Ehemba, "Determination the diffusion lenght of the minority carriers by photocurrent capacitance measurement and determination of the electric parameters of a $CuInSe_2$ thin film solar cell electrodeposited on flexible substrate of Kapton",University Cheikh Anta Diop of Dakar, Laboratory of Semiconductors and Solar Energy, (2015).